



# Exposure Assessments for Children

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# Human Exposure Definitions

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**Exposure** (potential dose)

The contact *at visible external boundaries* of an individual with a compound for a specific duration of time.

**Dose** (absorbed dose)

The amount of compound that crosses the external barrier into the body.



# Exposure Assessment

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Exposure assessments (half of a risk assessment) are developed to characterize "real-life" situations

- Identify potentially exposed populations
- Identify potential exposure pathways
- Quantify the magnitude, frequency, and duration of chemical exposure



# Direct Assessment

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- Measure receptor contact with chemical concentration in the exposure media over an identified period of time
- Personal monitoring techniques are used to directly measure exposure to an individual during monitored time intervals
- Biomarkers are an indicator of absorbed dose that resulted from direct exposure.



# Indirect Assessment

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- To estimate exposure, use
  - available information on concentrations of chemicals in exposure media,
  - information about when, where, and how individuals might contact the exposure media,
  - algorithms and a series of exposure factors (i.e., pollutant transfer, pollutant uptake)
- Because of difficulty performing direct exposure assessments, indirect assessments are often used to perform the risk assessments required to make regulatory decisions.



# Exposure Factors

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Indirect exposure assessments require data on the following exposure factors:

- Contaminant concentrations in the exposure media in the environment where the individual spends time
- Contact rates of the individual with the exposure media
- Contaminant transfer efficiency from the contaminated medium to the portal of entry
- Contaminant uptake rates through portal of entry
- Human activities



# Human Activities

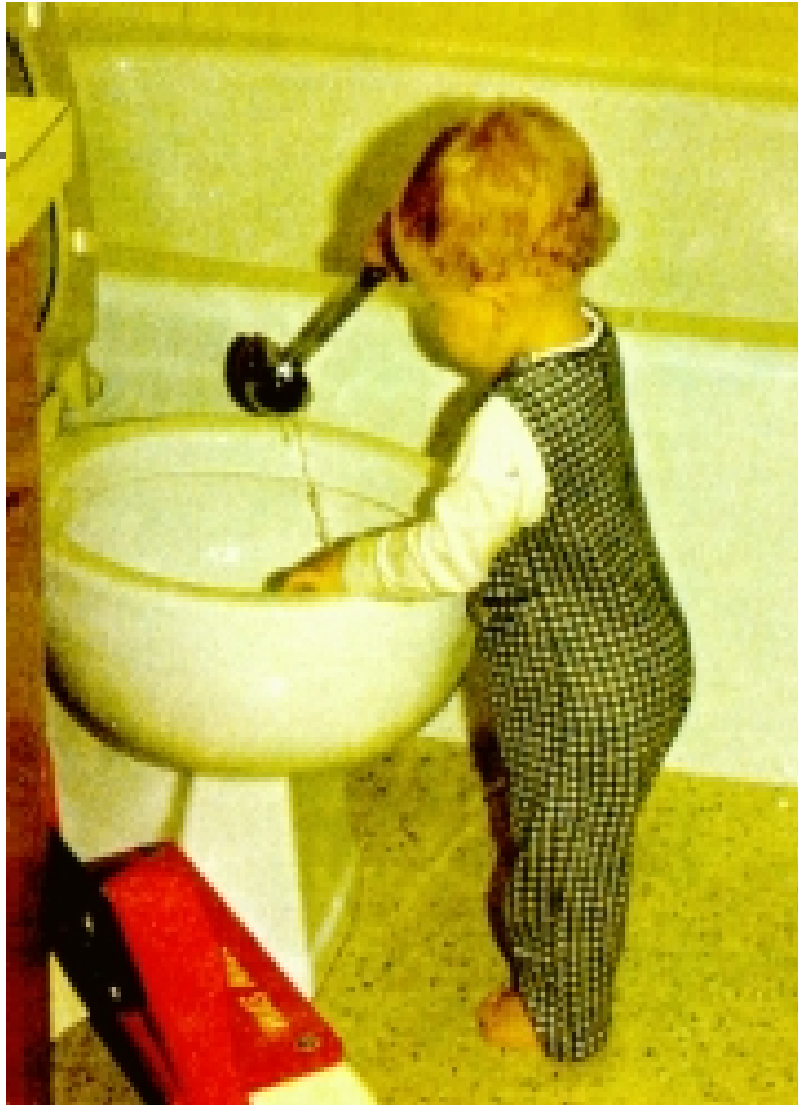
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- Activity patterns provide information about when, where, and how individuals might contact exposure media.
- Contact rates, transfer efficiencies, and uptake rates are all a function of activity patterns.
- Tremendous variability in activity patterns for children.

## Baby Blues







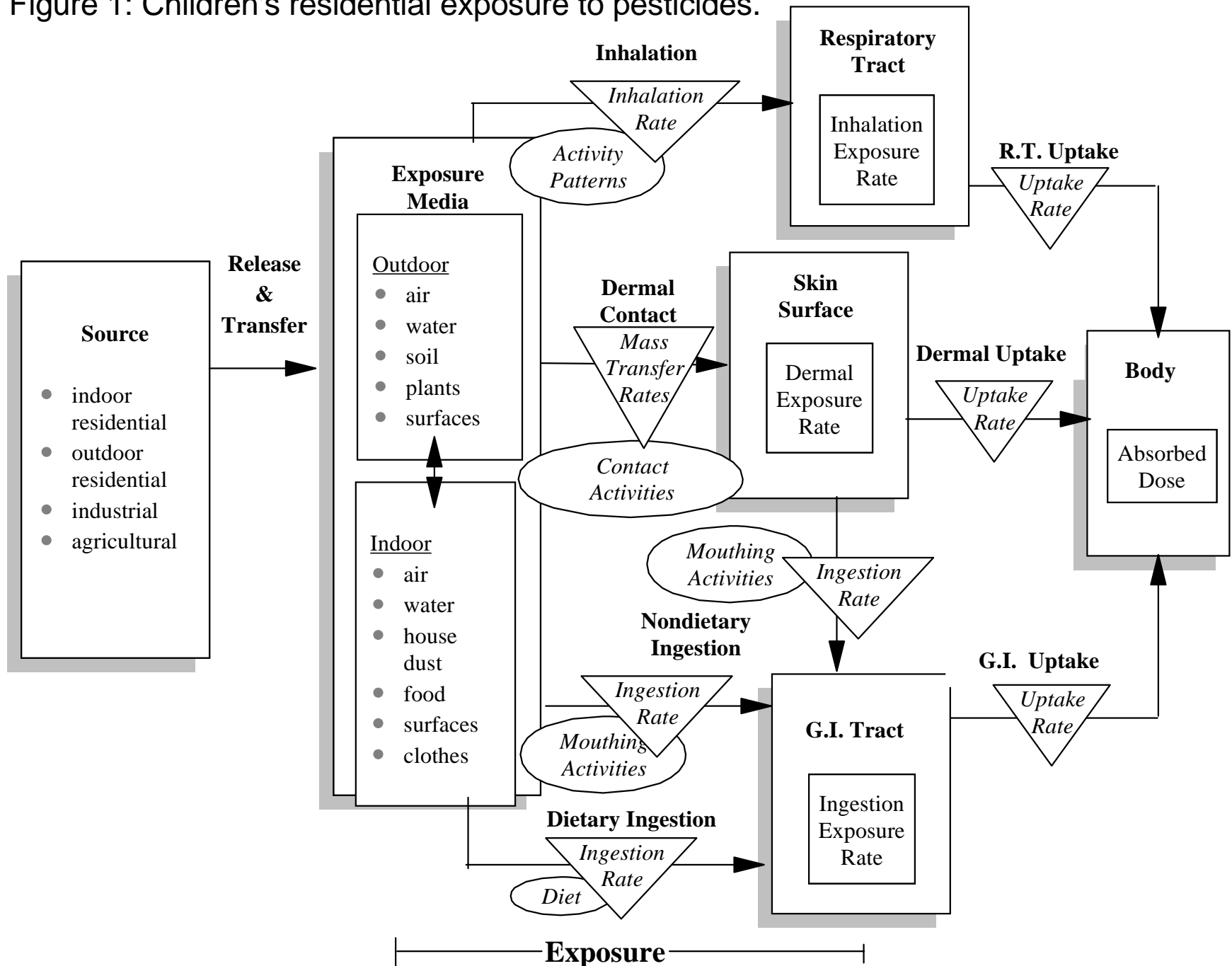


# Approach

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- Develop a conceptual model
- Identify potential exposure pathways and scenarios
- Define algorithms, exposure factors, and data requirements
- Perform a screening assessment to evaluate the range of exposures for, and significance of, each pathway
- Identify data gaps and uncertainties associated with current defaults
- Design research needed to address data gaps and reduce uncertainty

Figure 1: Children's residential exposure to pesticides.





# Exposure Pathways

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- In general terms, a pathway is defined as the course that a chemical takes from its source to the receptor's portal of entry.
- To specifically evaluate potential for exposure, pathways are defined here by the exposure medium and the route of exposure.
- The pathway crosses the environmental medium with the human activity that leads to exposure
- Examples:
  - Indoor air → Inhalation
  - Turf → Dermal contact



# Exposure Scenarios

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- For any given pathway there are a set of associated exposure scenarios
- Exposure scenarios combine
  - **Source** (industrial, residential)
  - **Population** (age group, geographic location, SES)
  - **Timeframe** (acute, short term, chronic)
  - **Microenvironment** (indoors, outdoors, home, daycare/school, other, in transit)
  - **Macroactivity** (active play, quiet play, sleeping, eating)



# Exposure Pathways vs Exposure Scenarios

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- Systematically identify potential exposure pathways to frame exposure assessments
- Identify exposure scenarios to specify values of exposure factors and to estimate distribution of exposure by any given pathway
- To identify exposure scenarios, need to use appropriate age/developmental benchmarks for categorizing children



# Characteristics of Children that Influence Exposure

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- Physiological characteristics
- Behavioral characteristics
  - Development (motor capacity, mouthing)
  - Physical Activities
  - Diet and eating habits
- Other characteristics
  - Gender
  - Socioeconomic Status
  - Race/ethnicity



# Exposure Algorithms

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- For each route, the algorithm mathematically expresses exposure as a function of
  - chemical concentration in the exposure medium
  - contact rate
  - rate of transfer from the exposure medium to the portal of entry
  - exposure duration
- Aggregate assessments include all three exposure routes: inhalation, dermal contact, and ingestion
- Ingestion can be divided into two subroutes, dietary and non-dietary ingestion.





# Children's Activity Pattern Data

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- Microenvironment  
The location the child occupies
- Macroactivity  
General activities such as watching TV, eating dinner, taking a shower
- Microactivity  
Detailed actions that occur within a general activity, such as hand-to-surface and hand-to-mouth behavior



# Inhalation Exposure

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For each microenvironment-macroactivity combination (me/ma), inhalation exposure over the 24-hr period is defined as

$$E_{\text{inhale\_me/ma}} = C_{\text{air\_me}} \times IR_{\text{ma}} \times ED_{\text{me/ma}}$$

$C_{\text{air\_me}}$  = air concentration measured in the microenvironment (mg/m<sup>3</sup>)

$IR_{\text{ma}}$  = child's respiration rate for the macroactivity (m<sup>3</sup>/h)

$ED$  = time spent in that me/ma over the 24-hour period (h/24h)

Exposure over the 24-hr period is the sum of all of the me/ma exposures.



# Inhalation: Data Requirements

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- Definition of important microenvironment-macroactivity combinations (me/ma) for inhalation exposure
- Air concentration in each microenvironment
- Inhalation rate for each me/ma  
(Based on child's age and weight)
- Amount of time child spends in each me/ma over 24-hrs



# Macroactivity Data

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- Macroactivity information for an individual contains at least one complete day of sequential location/activity data for each discrete major behavior. There are 9 studies that recorded such data, but only 4 include data on children.
- Data from all 9 studies contained in CHAD; a relational database using a common set of codes for activities, locations, intensity levels, and questionnaire information.
- Limitations of existing macroactivity data:
  - **Activity codes are much too broadly defined and ignore many child-oriented behaviors**
  - **Location information may not be sufficient to assess dermal exposure**



## Dermal Exposure - Macroactivity Approach

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For each microenvironment-macroactivity combination (me/ma), dermal exposure over the 24-hour period is defined as

$$E_{\text{dermal\_me/ma}} = C_{\text{surface}} \times TC \times ED$$

$C_{\text{surface}}$  = surface loading measured in the microenvironment (mg/cm<sup>2</sup>)

TC = dermal transfer coefficient for the me/ma (cm<sup>2</sup>/h)

ED = time spent in the me/ma over a 24-hr period (h/24h)



# Dermal: Data Requirements

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- Definition of important microenvironment-macroactivity combination (me/ma) for dermal exposure
- Transferable surface loading in each microenvironment
- Time child spends in each me/ma over 24-hrs
- Transfer coefficient for each me/ma  
(Data need to be generated experimentally based on child age and behavior)
- Clothing pattern for the child that would affect the surface area available for transfer and absorption



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## Dermal Exposure - Microactivity Approach

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For each microactivity, dermal exposure over the 24-hour period is defined as

$$E_{\text{dermal\_mi}} = C_{\text{surface}} \times TE \times SA \times EF$$

- $C_{\text{surface}}$  = surface loading measured in the microenvironment ( $\mu\text{g}/\text{cm}^2$ )
- TE = transfer efficiency, fraction transferred from surface to skin (unitless)
- SA = surface area contacted ( $\text{cm}^2/\text{event}$ )
- EF = frequency of contact over a 24-hr period (events/24h)





# Dermal: Data Requirements

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- Definition of important microenvironments for dermal exposure
- Data on important microactivities that lead to contact with objects/surfaces
- Residue loadings for the objects/surfaces contacted
- Fraction of residue transferred from surface to skin during contact event (requires characterization of the contact for each microactivity)
- Surface area of objects/surfaces contacted
- Number of contact events over 24-hours



# Microactivity Data

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- Approaches to gathering data
  - Real-time hand recording
  - Videotaping
- Comparing results among studies is difficult due to differences in
  - Ages of children
  - Reported summary statistics
  - Categories of body parts and objects contacted
- Limitations
  - Few data sets, small sample sizes
  - Require knowledge on important contact parameters



# Indirect Ingestion Exposure

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For each microactivity resulting in indirect ingestion, exposure over the 24-hour period is defined as

$$E_{\text{ing/mi}} = C_x \times TE_x \times SA_{xm} \times EF$$

$x$  = hand, object, food item, or anything else that enters the mouth

$C_x$  = surface loading on  $x$  ( $\mu\text{g}/\text{cm}^2$ )

$TE_x$  = transfer efficiency, fraction transferred from  $x$  to mouth  
(unitless)

$SA_x$  = area of  $x$  that is contacted by the mouth ( $\text{cm}^2/\text{event}$ )

$EF$  = frequency of indirect ingestion events over a 24-hr period  
(events/24h)



# Indirect Ingestion Data Requirements

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- Information on microenvironments/macroactivities that lead to indirect ingestion (including information on locations where an individual child consumes foods)
- Information on what surfaces, body parts, toys, etc., are mouthed
- Information on handled and consumed foods for an individual child
- Surface loadings for any objects or surfaces (including hands) mouthed by children
- Information on child's hand washing practices
- Transfer efficiency from the surface (including hands) to mouth during a mouthing event
- Number of mouthing events during a 24-h period, and
- Surface area of object mouthed



# Direct Dietary Ingestion

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For each food ingested, exposure over the 24-hour period is defined as

$$E_{\text{food}} = C_{\text{food}} \times W$$

$C_{\text{food}}$  = concentration of chemical in food item ( $\mu\text{g}/\text{kg}$ )

$W$  = weight of food item consumed ( $\text{kg}/\text{d}$ )

- Total dietary exposure over the 24-hr period is the sum of all of the foods consumed
- Data requirements include specific information about the types and quantities of foods eaten as well as the concentrations of chemical in these foods



# Challenges

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- Identify those chemicals, pathways, and activities that represent the highest potential exposures to children
- Determine the factors that influence exposures to children
- Develop approaches for measuring multimedia exposures to children, including approaches that account for important activities that take place in home, school, and daycare settings
- Generate data on multimedia chemical concentrations, biomarkers, and exposure factors that can be used as inputs to aggregate exposure models for children